

This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

**As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.**

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
F02B 1/12, 7/00

A1

(11) International Publication Number: WO 00/61927

(43) International Publication Date: 19 October 2000 (19.10.00)

(21) International Application Number: PCT/SE00/00660

(22) International Filing Date: 7 April 2000 (07.04.00)

(30) Priority Data:
9901255-1 9 April 1999 (09.04.99) SE

(71) Applicant (for all designated States except US): SCANIA CV
AKTIEBOLAG (publ) [SE/SE]; S-151 87 Södertälje (SE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): CARLSSON, Göran
[SE/SE]; Fruktvägen 75, S-155 31 Nykvarn (SE).
HULTQVIST, Anders [SE/SE]; Vinkelvägen 5, S-245 35
Staffanstorps (SE).

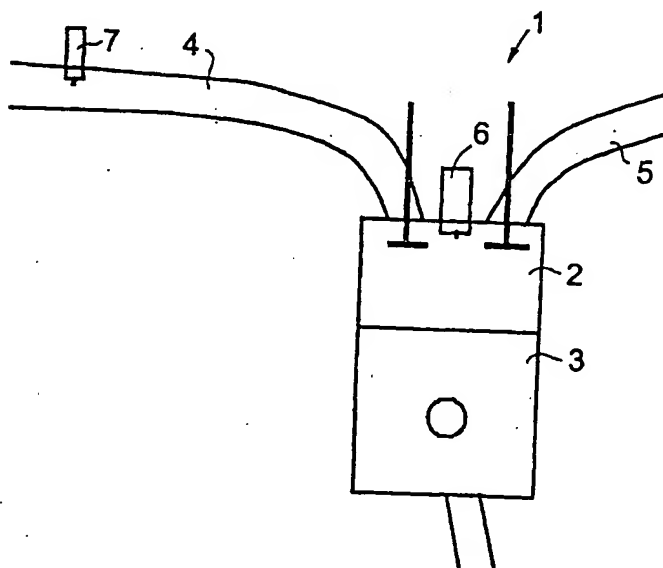
(74) Agent: WALDEBÄCK, Hans; Scania CV AB, Patents, S-151
87 Södertälje (SE).

(81) Designated States: BR, DE, JP, US, European patent (AT, BE,
CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC,
NL, PT, SE).

Published

With international search report.
In English translation (filed in Swedish).

(54) Title: METHOD FOR FUEL INJECTION IN AN INTERNAL COMBUSTION ENGINE AND INTERNAL COMBUSTION
ENGINE



(57) Abstract

A method for fuel injection in a combustion engine of piston and cylinder type with compression ignition (1), whereby a controlled quantity of fuel is supplied to the combustion chamber (2) for each working cycle, is distinguished by the fact that a first "shot" of said controlled fuel quantity is supplied (7) during the air inlet phase (4) in order to establish a homogeneous fuel/air mixture, and that a second "shot" is supplied (6) directly to the combustion chamber (2) as injected fuel. The invention also relates to a combustion chamber operating according to the method.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

Method for fuel injection in an internal combustion engine and internal combustion engine

Field of the invention

5

The present invention relates to a method for fuel injection in a combustion engine of piston and cylinder type in accordance with the preamble to patent claim 1, and to a combustion engine in accordance with the preamble to patent claim 6.

10 State of the art

The problem of high NO_x emissions from conventional diesel engines arises from very high combustion temperatures in limited portions of the cylinder at the time of ignition, due to combustion taking place along a defined combustion front with low λ numbers
15 (air/fuel ratios).

The various arrangements which have been adopted with a view to preventing these emission problems of diesel engines include combustion engines which are known by the designation ATAC (Active Thermo Atmospheric Combustion) and may popularly be said
20 to be a combination of a diesel engine and an Otto engine. In their case, a premixed fuel/air mixture is introduced into the cylinder and is ignited by compression when the working piston is in the vicinity of its top dead centre position in the ignition phase. ATAC engines afford considerable advantages, particularly in the form of small or no NO_x discharges and high efficiency which approaches that of diesel engines. ATAC
25 engines overcome the problem by using a substantially leaner mixture (with high λ number) resulting in lower combustion temperatures due to combustion being initiated substantially simultaneously within widespread regions of the combustion chamber. The overall result is a more uniform temperature distribution.

30 In combustion engines of the kind which employs combustion of a homogeneous premixed fuel/air mixture, it has been found possible to overcome the emission problem with regard to harmful pollutants. However, this type of engine suffers from a number of disadvantages, including a narrow load range. This means that acceptable operation

depends on ignition taking place in a limited situation close to the top dead centre position (TDC) of the working piston. The commencement of combustion depends on several parameters, but primarily on the temperature in the combustion chamber. As this temperature itself depends to a large extent on the charging pressure and the load, the point in time at which the ignition of the gas mass commences will vary substantially. This means poor engine efficiency and that the thermal loading on the engine will be large if ignition takes place too early, which tends to occur at high loads. If ignition is late, the efficiency will likewise be poor and the combustion incomplete, resulting in high HC (hydrocarbon) emissions, which tends to occur at low loads. A further problem is that the ignition commencement point is not stable. An example is where the ignition commencement point is in the region around the dead centre position of the working piston. An infinitesimal change in the ignition commencement time relative earlier ignition towards TDC causes an infinitesimal increase in the engine's thermal loading, resulting in higher temperature during the next cycle, and so on, thereby driving the ignition commencement point still earlier relative to TDC in an escalating pattern with harmful consequences.

Object and most important characteristics of the invention

An object of the present invention is to indicate a method and a combustion engine which eliminate or at least reduce the disadvantages of the state of the art.

This object is achieved according to the invention by a method for fuel injection of the kind mentioned in the introduction in accordance with the characterising part of patent claim 1 and by designing the combustion engine according to the features in the characterising part of patent claim 6.

The advantages of combustion engines of the kind which employs combustion of a homogeneous premixed fuel/air mixture are thus maintained but the disadvantages of such engines are avoided. A first quantity of the fuel which is to be involved in the combustion process being introduced as early as the air inlet phase in order to establish a homogeneous fuel/air mixture, accompanied by the usual diesel engine practice that the remainder of the fuel which is to be involved in the combustion process is directly

injected into the cylinder for conventional initiation of its combustion, means that the first homogeneously mixed quantity serves as a preheater and ignition initiator for the quantity of fuel injected subsequently.

5 The principle of the invention may be applied in all diesel engines and with different diesel fuels. In particular, the invention may be applied to operation with fuels that do not readily ignite, such as ethanol and methanol. In conventional diesel engines run on ethanol, it may in certain operating situations be possible to run the engine on pure ethanol, e.g. at high loads. At lower loads, however, problems arise with operating with
10 pure ethanol fuel, so a so-called ignition improver, e.g. a nitrated compound or, for example, polyethyleneglycol, has to be mixed into the fuel. However, ignition improving additives in the fuel entail not only increased costs but also, in many cases, adverse affects on the engine. Such additives do in particular involve risk of affecting the lubricating oil and of deposits in injection pumps and ducts, as well as problems with oil
15 cleaning equipment.

The invention makes it possible, without adding an ignition improver, to run diesel engines on fuels which do not readily ignite, such as ethanol, since the homogeneously mixed first "shot" of fuel will in practice act as an ignition improver and also, as above, as
20 a preheater, so that the injected second "shot" ignites reliably at the desired time.

In diesel engines with more conventional fuels, such as diesel oil, the invention is particularly valuable during cold starts but is also applicable in other operating situations.

25 Engine operation may be optimised by varying the ratio between the first and second fuel shots. It may be mentioned, by way of example, that in normal running at full load it may be possible to supply a small first shot of fuel, or even no fuel at all, in order to establish a homogeneous fuel mixture, while at lower loads it is desirable to have a larger shot of established homogeneous fuel/air mixture. As the previously mentioned ATAC
30 combustion produces very low NO_x emissions, it may be advantageous to arrange that the fuel supplied at no-load and low loads should respectively consist exclusively or largely of the first shot of fuel which is supplied in order to establish a homogeneous fuel/air mixture. Good results may in principle also be achieved if the same quantity as that

constituting the first shot is used during the whole period of operation. The invention is thus not limited to improving the conditions for the normal combustion of directly injected fuel.

- 5 It is preferred that the first shot be supplied already in the air inlet pipe, as this arrangement ensures that the fuel/air mixture supplied to the cylinder is advantageously homogenised. Further advantages are achieved by various aspects of the invention and will be indicated by the following detailed description.

10 Brief description of drawings

The invention will now be described in more detail on the basis of an embodiment with reference to the attached drawings, in which:

- Fig.1 depicts schematically a combustion engine equipped according to the invention,
15 Fig.2 depicts schematically a control system used according to the invention, and
Fig.3 shows a diagram of the combustion pressure and the movement of the injection valve as a function of the crank angle of a combustion engine according to the invention.

Description of an embodiment

20

- The combustion engine 1 depicted schematically in Fig.1 is of diesel type and incorporates a cylinder space 2 and a piston 3 which is movable in the cylinder. The cylinder space 2 has leading into it an inlet duct 4 and leading out of it an outlet duct 5, each of them provided conventionally with appropriate valves. In the usual manner, at
25 least one injection nozzle 6 is installed in the cylinder head for direct injection of fuel into the fuel chamber.

- According to the invention, there is in addition a second fuel nozzle 7 installed in the inlet duct 4 so that the fuel supplied via this latter nozzle during the induction phase creates the
30 possibility of establishing a homogeneous fuel/air mixture.

The control system in Fig.2 incorporates a control unit 8 which is supplied with signals 9 representing engine operating parameters such as engine speed, load, engine temperature,

accelerator pedal position, exhaust composition etc. The control unit 8 is designed to control an injection valve 10 in order thereby to control the fuel quantity injected via the injection nozzle 6. The control unit 8 is also designed to control a second fuel valve 11 in order to control the supply of fuel to the second fuel nozzle 7. The control unit is
5 preferably programmed to optimise the ratio between the fuel quantities injected via the nozzles 6 and 7, the total quantity of fuel injected and, where applicable, the times when the respective injections take place relative to the engine's crank angle.

The diagram shown in Fig.3 thus illustrates the cylinder pressure as a function of the
10 crank angle and A_K denotes the cylinder pressure generated by the actual piston movement. The deviation of curve A from that line denotes the pressure increase due to fuel combustion. The first deviation from curve A_K is at point 12 and ΔP_1 denotes the pressure increase due to combustion of the first shot of fuel injected via the nozzle 7. Point 13 denotes a deviation from this curve A_F and is the point where fuel injected via
15 the nozzle 6 also becomes involved in the combustion process. The result is a pressure difference ΔP_2 . The invention thus achieves a first pressure increase ΔP_1 due to the combustion of the homogeneous fuel/air mixture and a corresponding temperature increase in the cylinder space, which temperature increase also causes reliable ignition of conventionally injected fuel at an acceptable time, and it may in principle be said that the
20 ignition of this latter fuel is shifted to an earlier time. In such situations as cold starts, the combustion process may otherwise commence only long after the top dead centre point.

The bottom curve in Fig.3 relates only to the crank angle scale of the diagram and indicates the injection valve's opening 14 and closing 15, between which the other shot of
25 fuel is injected via the nozzle 6.

The invention may be varied within the scope of the claims, and in particular the ratio between the various "shots" referred to above may be adapted to cater for a variety of operating situations. It is nevertheless possible in principle to run with a fixed "first fuel
30 quantity" throughout the operating range, in which case this quantity corresponds to the "no-load quantity", which is normally equivalent to about 5-10% of the "full-load quantity".

It is also possible to arrange the positioning and number of the injection nozzles according to the conditions prevailing in present-day engines. The configuration and positioning of the nozzle 6 and the relating fuel circuit may be conventional, while the circuit pertaining to the nozzle 7 may take the form of a very simple injection
5 arrangement.

It is also possible to supply a variety of fuels, which differ in how readily they ignite, to form the respective first and second "shots", while at the same time operation may be further optimised for various operating situations such as starting, cold starting, low load,
10 medium-high load, high load.

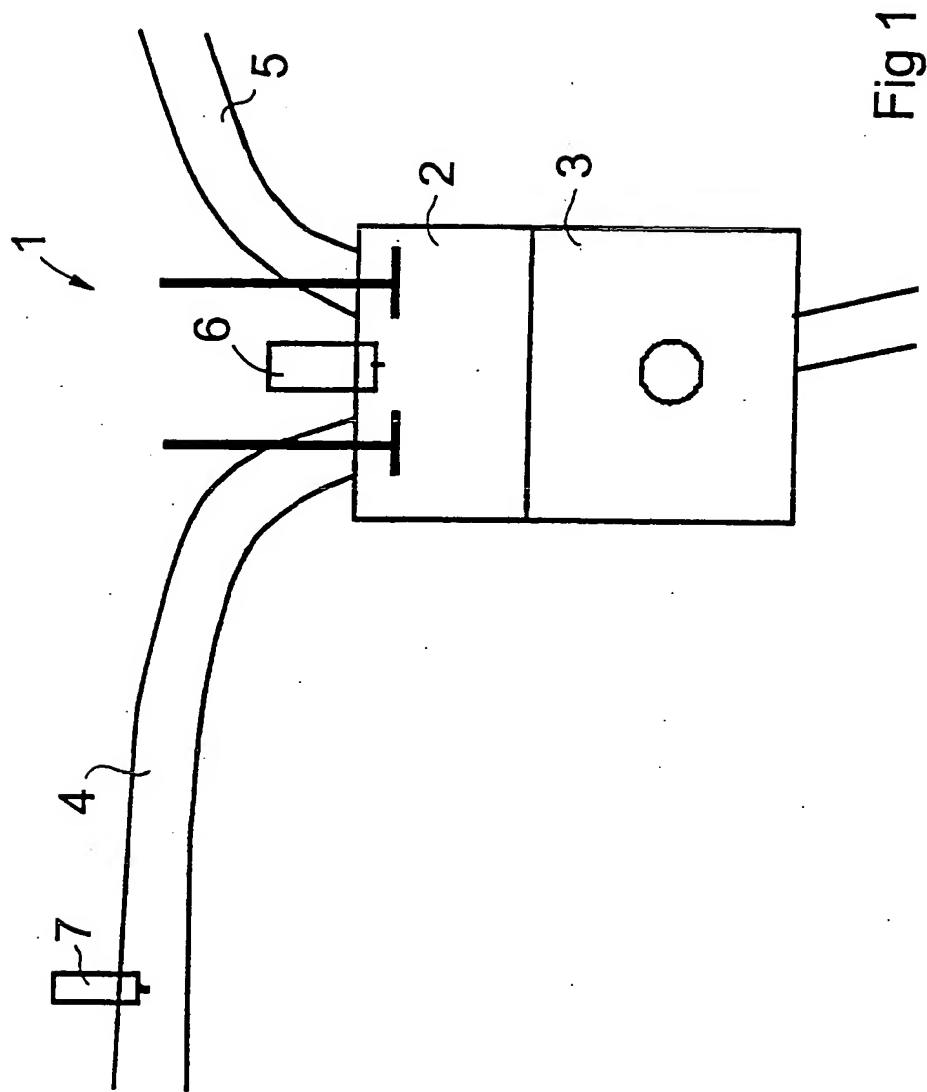
Experiments conducted with an engine operating according to the invention indicate that NO_x and particle discharges will be lower than those from conventional diesel engines run on methanol fuel containing ignition improvers. Some reduction in fuel consumption
15 may also be expected.

It is preferred that the first "shot" be already supplied to the inlet air in the inlet line, as in the embodiment described, thereby ensuring homogenisation of the mixture, but it may also be supplied directly to the cylinder during the air inlet phase. Using a so-called
20 "common rail" injection system for the injector 6 makes it possible to achieve a homogeneous mixture by means of an extra injection at the appropriate time. The spray nozzle 7 may then be omitted. Such cases afford the advantage of being able to use the same injection nozzle(s), although a controllable injection system has to be used. It may also be conceivable to use two different sprays in the cylinder, one of them to supply the
25 first "shot", the other to supply the second.

Patent claims

1. Method for fuel injection in a four-stroke combustion engine of piston and cylinder type with compression ignition (1), whereby a controlled quantity of fuel is
5 supplied to the combustion chamber (2) for each working cycle, **characterised in** that a first "shot" of said controlled fuel quantity is supplied during an air inlet phase in order to establish a homogeneous fuel/air mixture, and that a second "shot" is supplied (6) to the combustion chamber (2) as injected fuel for conventional initiation of ignition.
- 10 2. Method according to claim 1, **characterised in** that the first "shot" of said controlled fuel quantity is supplied (7) to the inlet air (4) before the combustion chamber (2).
3. Method according to claim 1 or 2, **characterised in** that the ratio between
15 the first and second "shots" is controlled on the basis of operating parameters (9) such as engine speed, load, engine temperature, accelerator pedal position and/or exhaust composition.
4. Method according to claim 1, 2 or 3, **characterised in** that the ratio between
20 the first and second "shots" is kept at about 1/20 to 1/10.
5. Method according to any one of the foregoing claims, **characterised in** that ethanol, methanol or diesel oil is used as fuel.
- 25 6. Combustion engine of piston and cylinder type with compression ignition (1), incorporating devices for supplying a controlled fuel quantity to the combustion chamber for each working cycle, **characterised in** that it incorporates first devices (7,11) for supplying a first "shot" of said controlled fuel quantity during an air inlet phase in order to establish a homogeneous fuel/air mixture, and second devices (6,10) for
30 supplying a second "shot" directly into the combustion chamber (2) as injected fuel at the time for conventional initiation of ignition.

7. Arrangement according to claim 6, **characterised in** that the first "shot" of said controlled fuel quantity is arranged to be supplied to the inlet air (4) before the combustion chamber (2).
- 5 8. Arrangement according to claim 6 or 7, **characterised in** that said first device includes a fuel nozzle (7) delivering into an inlet duct (4) leading to the cylinder.
9. Arrangement according to claim 6, 7 or 8, **characterised by** a control unit (8) which, on the basis of operating parameters (9), is arranged to control the injection.



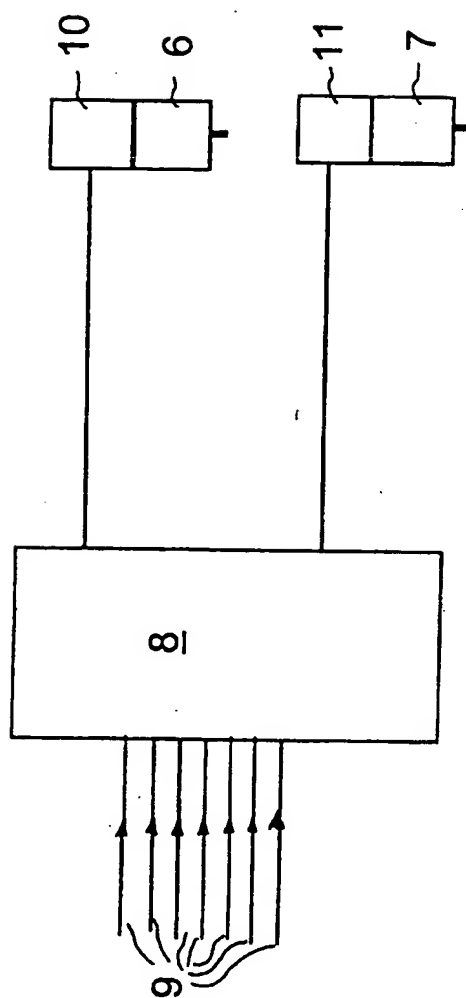


Fig 2

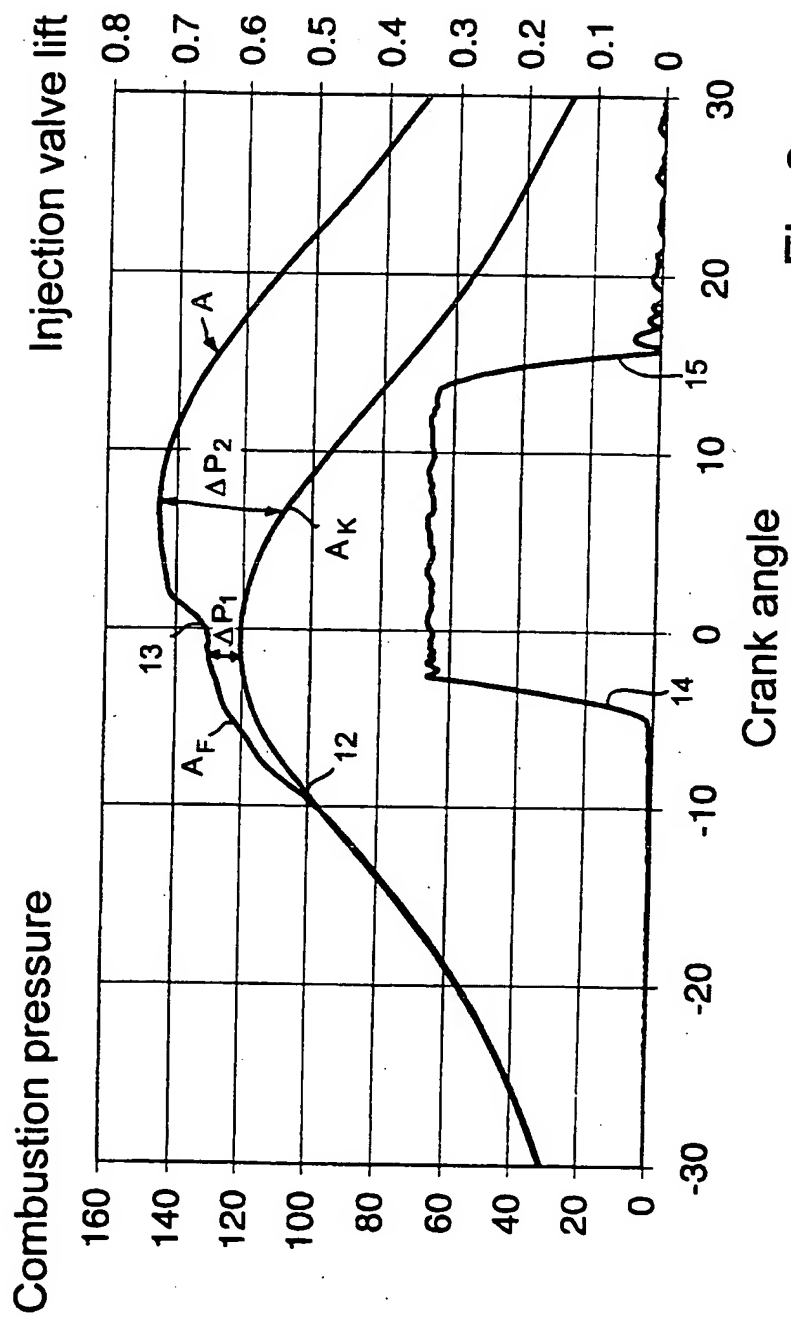


Fig 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/00660

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02B 1/12, F02B 7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 699512 A (ERLING POPPE), 11 November 1953 (11.11.53), page 1, line 38 - line 52; page 1, line 81 - line 95, figures 1-3 --	1-9
X	DE 19519663 A1 (DAIMLER-BENZ AKTIENGESELLSCHAFT), 15 May 1996 (15.05.96), column 2, line 30 - column 3, line 26, figures 1,2 --	1-9
X	US 4572133 A (BAGO), 25 February 1986 (25.02.86), figures 1,2, abstract -- -----	1-9

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

- * Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
 - "E" earlier document but published on or after the international filing date
 - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 - "O" document referring to an oral disclosure, use, exhibition or other means
 - "P" document published prior to the international filing date but later than the priority date claimed
 - "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 - "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 - "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 - "&" document member of the same patent family

Date of the actual completion of the international search

28 June 2000

Date of mailing of the international search report

2000-07-25

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Dan Ionesco / JA A

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.

PCT/SE 00/00660

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 699512 A	11/11/53	NONE	
DE 19519663 A1	15/05/96	NONE	
US 4572133 A	25/02/86	NONE	